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Sponsored by the American Philosophical Society and the National Science Foundation in the Hall of the Society, February 10 and 11, 1955

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THE NATURE OF THE CONFERENCE AND ITS IMPLICATIONS

RICHARD H. SHRYOCK

The Johns Hopkins University

THE papers here published were presented at a Conference on the History, Philosophy, and Sociology of Science, sponsored jointly by the American Philosophical Society and by the National Science Foundation and held at Philadelphia in the Hall of the Society on February 10 and 11, 1955. The Foundation suggested the Conference, provided secretaries, and met the costs for the purpose of exploring the fields mentioned and in order to clarify their respective needs.

Following the proposals of a Steering Committee which met on the preceding December 8, thirty-five scholars were invited to participate.[1] The number was limited in order to permit free discussion and all but three or four were able to attend. The Conference opened with a preliminary statement by Dr. Harry Alpert on the possible relations of the National Science Foundation to the three disciplines under consideration. A session was then devoted to each of the fields in turn. Professor Henry Margenau spoke on the Philosophy of Science, Professor Bernard Barber on the Sociology of Science, and Professor I. Bernard Cohen on the History of Science. General discussion followed each paper and at a final session an interpretation of the whole was presented by Professor Philipp G. Frank. In conclusion, Dr. Alan T. Waterman, Dr. Raymond Seegar, and Dr. Alpert commented on the contributions which they believed the Conference would make to the Foundation's interest in the humanistic and social aspects of science.

The introductory papers followed, in general outline, a number of questions proposed in advance by the Steering Committee. Most of these were of an exploratory nature and related to activities in the fields, their personnel and financial resources, their training and research needs, and their values for science and for education. A final question invited suggestions on how the National Science Foundation might support research and education in these areas.[2]

* * *

[1] See appendix for the members of the Steering Committee and for the list of those invited to participate.

[2] The complete questions are given in the appendix.

Each of the papers speaks for itself and there is no need for editorial summaries. One may note, however, certain views which are shared by two or more authors and which therefore are probably representative of opinion in these disciplines. Professors Margenau and Frank agree that science has been fragmentized, that scientists tend to become technicians who have no vision of larger relationships, and that the only way to overcome these limitations is to provide philosophic and historical perspectives on contemporary research. Such perspectives are needed by science in its own behalf, as a means of humanizing the whole field and of providing it with some semblence of unity. Broader outlooks are also needed in order to adjust scientists to the social environment in which they operate.

Professors Margenau and Frank view the philosophy of science as an aspect of science itself, but note that it is neglected by most scientists—with the result that there is a lag in the development of basic concepts. But since each scientist must have *some* philosophy, the result is that many continue to think in terms of older frames of reference of which they are hardly aware. The slow development of a philosophy of science has unfortunate implications for society, since it is this aspect of scientific thought which eventually influences education and morals. Such contemplative adjustments cannot keep up, at present, with accelerating advances in technology. Professors Margenau and Frank also share the opinion that the teaching of science —the most direct means for orienting the public —tends to be dull because it is largely factual in content. Teaching could be enlivened and made more meaningful by presenting the technical materials in a philosophic and historical setting.

Professor Barber conceives the sociology of science as an aspect of sociology, much as Professor Cohen thinks of the history of science as a phase of general history—neither viewing their respective disciplines as parts of science as such. Each of these fields, although focusing on science, views it as it were from the outside. Professor Barber, however, emphasizes the values which sociology may have for science, notably in making

clear the social and cultural circumstances which make for scientific progress.

Professor Cohen joins with Professors Margenau and Frank in emphasizing the values which philosophy and history may have for the scientists themselves. And he notes, in addition, the services rendered by the history of science to philosophy and sociology. But he urges that history has its own integrity and should not be subordinated as an applied field—or source—for these two related disciplines. He also urges that philosophers and sociologists who are interested in science should become more familiar with its history.

Professors Barber and Cohen agree with the first two authors in regard to the importance of their fields for education. But they emphasize somewhat distinct implications for teaching. Thus, Professor Cohen notes the service the history of science can render by cultivating a respect for ideas among students. In so doing, history may also help the latter to acquire some understanding of the philosophy and sociology of science. Professor Barber distinguishes between the value of his field for non-science students and for those who major in science. Professional students, he points out, should be oriented in the sociology of their particular guilds.

All the speakers deplore the relative neglect of their subjects in the university world and the associated lack of qualified personnel. Professor Frank suggests that the situation results from the border-line nature of these disciplines, at least as far as philosophy and history are concerned. Historians, for example, assign the history of science to scientists, while the latter relegate it to the historians. The field thus falls between two stools. One may add that other factors are probably involved. To cite the historians again, many of them appreciate the significance of science but avoid its history because they do not feel qualified to deal with technical themes.

Whatever the explanation of present difficulties, the speakers are one in declaring that personnel is the "bottleneck" in the whole situation. The most pressing needs, they agree, are to attract good men into these disciplines and to assist the few who are already active therein. Pre-doctoral fellowships, post-doctoral fellowships to supplement earlier training, special conferences, and research grants are advocated as the means for providing qualified and adequate personnel.

The Conference, accepting these suggestions, emphasized them in a series of recommendations which were submitted to the National Science Foundation and are appended herewith. As a means for implementing the proposed activities, the Conference also recommended that the Foundation set up an Advisory Panel for the History, Philosophy, and Sociology of Science. The Foundation has subsequently taken this action.

* * *

Discussions which followed the formal papers indicated acceptance of many of the generalizations mentioned. This was hardly surprising, since most of those present were selected because of their known interest in the fields under discussion. But divergent opinions also emerged. One scientist, for example, questioned the validity of sociologic studies on the ground that sociologists often lacked an understanding of biologic factors in society. This elicited the reply that, in so far as the point was valid, it was equally true that biologists lacked an understanding of social forces. The moral seemed to be that interdisciplinary orientation was desirable in both areas.

Another scientist questioned some of the values claimed by the speakers. He held that the three fields were "ancilliary disciplines more closely connected with history, philosophy, and sociology respectively than they are to science." History was said to be useful in arousing public appreciation of science, but—by implication—it could offer little to the scientist himself. The sociology of science, likewise, would be of little import to scientists in the strict sense, though it could be most helpful in clarifying the social implications of technology. This comment apparently related to the impact of science on society, whereas Professor Barber had discussed chiefly the reverse influence of society on science.

As far as the philosophy of science was concerned, the critic agreed with Professors Margenau and Frank that this subject was an aspect of science. But he went further in holding that "the most significant modern contribution to philosophy is synonymous with science itself." In other words, "this aspect of philosophy . . . cannot be pursued separately from scientific research," and it therefore need not be considered as a distinct entity. In supporting science, he held, the Foundation is *ipso facto* promoting the philosophy of science as well.

Some of those present, however, were convinced that the scientist whose philosophy is simply inherent in his research lacks the perspec-

tives provided by broader philosophic knowledge. It was also observed that science raises questions pertinent to general philosophy and that the scientist should be made aware of these wider implications of his own work. In this connection, Professor Margenau suggested that a more continuous exchange of ideas between scientists and philosophers would be mutually advantageous.

Professor Herbert Dingle was requested, as the sole European scholar present, to comment on the general discussions. His observations, reported more fully below, emphasized a basic distinction between the history and philosophy of science on the one hand, and the sociology of science on the other. The first two, he pointed out, are—or should be—concerned solely with *science* (with ideas, discoveries), while sociology relates instead to *scientists* (to the social relations of a guild). In consequence, interests in these two areas are quite distinct. Thus, a new theory or discovery would be of great importance to historians or philosophers but of little concern, in itself, to sociologists. The history of science, moreover, should be consciously "detached" from sociologic phenomena, lest the evaluation of ideas as such be contaminated by social theory or by irrelevant considerations of time, place, or circumstance. As an example of this danger, Professor Dingle cited the treatment accorded the history of scientific ideas under totalitarian régimes.

The sociology of science, Dr. Dingle added, is of great value; but it can be developed "only by writing first the history of science in itself, and then, as a separate investigation, considering why its successive steps occurred when, where, and how they did." In view of this sharp distinction between historical and sociologic studies, he questioned the advisability of associating the two in a single conference.

Several participants expressed disagreement with these views. Their opinion was that the history of science should include both intellectual and related social developments. The divergence here may have been partly semantic in nature. It was apparent that Professor Dingle had indicated one way in which to present the science of the past; that is, to trace (1) its intellectual or "internal" history, and then to present quite separately (2) its social or "external" development. But certain members questioned the assumption that the first of these steps constituted *the* history of science, to the exclusion of its social aspects. They preferred to think of the history of science as including, in its entirety, both the intellectual and the social themes.

If this denotation of "history" is accepted, it would follow that historians would share at certain points the interests of sociologists as well as of philosophers. They would, with the latter, be concerned with emerging theories; but they would also, with the former, be intrigued by—let us say —the changing relations of science to the State.

No doubt the difference of opinion here went deeper than definitions. Some participants held that distinct investigations of intellectual and social history, as advocated by Professor Dingle, might be admirable in themselves but would not add up to the final word. Also needed, they held, are studies which present the intellectual and social factors in close juxtaposition. For one thing, social presuppositions or interests often insinuate themselves into what seem at first glance to be the most objective ideas of the investigator, with the result that it may be misleading to omit the role of environmental factors even in tracing ideas as such. In other words, it is very difficult to isolate ideas in so "pure" a state that they contain no social ingredients.

More obvious is the fact that it is sometimes misleading to attempt any evaluation of ideas outside their social context. As an example of this sort of situation, one member cited the medical history of the eighteenth century. The medical "systems" advanced during that era now seem naive because the theories involved were quite unverifiable. Yet they were accepted by outstanding medical men. In contrast, the physicists and astronomers of the time seem to have been more "scientific" in that they already demanded verification. Should one then, in dealing with this medical story, just trace the ideas as such and risk leaving the impression that physicians were inherently less sophisticated or less logical than were physicists? Or should one complete the history of ideas for this century and perhaps the next, and then go back over the same periods in a second study (or volume) which deals only with the social background?

It would seem more effective procedure, in the case noted, to deal with both ideas and circumstances in a common context. This would involve presenting the ideas, noting their limitations, and attempting to explain these limitations. Such an explanation would take cognizance of the relative complexity of biologic phenomena, but it would

also have to consider social factors which may have conditioned medical thinking.

What, for example, of the fact that medical scientists—unlike physicists—could only pursue research in the little time left over from their practice of an art? (The professional situation was analogous to that which would have obtained in astronomy, if all research therein had been done by sea-captains.) And what of the fact that medicine, unlike physics or astronomy, operated within a dense atmosphere of human hopes and fears? Denied a free use of its basic materials by moral considerations, medicine was at the same time under constant pressure to achieve results of immediate utility. Rational medicine needed theories but could hardly await their verification in terms acceptable to contemporary physical scientists.

In other words, the outcome in a scientific field is often the result of a continuing interplay between ideas and their social environment. And this exchange, one would think, can be best understood if the two categories are viewed in direct relation to one another. This does not necessarily mean simultaneous consideration; that is, in the one paragraph or even in the one chapter. But we do need single studies in which the process of interplay is made as clear as possible.

Participants who accepted these views were not necessarily indifferent to the dangers which Professor Dingle cited. No one denied that social perspectives might, under certain conditions, distort the evaluation of ideas. But to abandon a procedure simply because it can be abused, seemed much like throwing the baby out with the bath.

It was not clear, moreover, that Professor Dingle's device for avoiding abuses would necessarily achieve this end. A Marxian historian, for example, can conceivably eliminate all social content from his narrative—restricting himself to pure ideas—and yet still evaluate these abstractions in terms of his own philosophy. Explicit social data or theories might have supplied him with more ammunition, so to speak, but he can still employ resources which are simply implicit in his own thinking. The problem here becomes that of objectivity in general, which can hardly be solved by excluding particular content elements.

The views just outlined were apparently shared by many of those who took part in the discussions. Yet all felt indebted to Professor Dingle for bringing this issue into the open, so that even those who did not share his opinion found it well to formulate their own views in a more precise manner.

The majority plainly held, despite the questions raised, that the philosophy, history, and sociology of science have a certain autonomy of their own, as well as relationships to the larger fields of which they are, respectively, component parts. So, too, was there considerable agreement that the history of science has much in common with the philosophy of science on the one side and with the sociology of science on the other. Finally, the concensus of opinion was that these three fields, although now neglected, offer potential values to science and to education which should be brought to a higher degree of realization. These conclusions became the basis for the recommendations made to the National Science Foundation, which represent the tangible outcomes of the Conference.

The editor is moved to make one concluding observation which relates to the implications of these fields for education and for general enlightenment. It is a truism that we are living—and have been living for some time—in "a scientific age." Yet there is little evidence that the American public has any better realization of the nature of science —of "what it is all about"—than it had a century ago. Nor is there much evidence that technical courses in science, as usually given in the schools, are likely to improve this situation. Students, scientists themselves, and the public at large would profit by more general understanding of how science operates and of the role it now plays in civilization; and such understanding can come only through some presentation of the history, the social background, and (for advanced students) the philosophy of science.

The manner in which students may be introduced to these disciplines depends upon the educational level concerned. The high schools are in a strategic position here, since they reach a relatively large population segment and also because they provide preliminary training and influence the attitudes of those students who are able to go on to college. The high schools can hardly offer distinct programs in the history and sociology of science; but their science courses could be made more stimulating if technical content were presented in an historical setting and with due reference to social implications. We cannot expect high school teachers to do this, however, as long as they themselves have secured no orientation of this sort in college. Much might be accomplished by teachers' conferences or

"institutes"—by "refresher training" of those already in service—but in the long run the broader outlook must be initiated at the college level.

The fact that college offerings in the history, philosophy, and sociology of science are now so meagre suggests that responsible authorities do not yet fully appreciate the influence which science has exerted on our entire culture. Or, at least, they have not yet come to grips with the problem of making this influence clear to undergraduates. No doubt it is assumed that technical courses provide all that students in general need to know about science, but this is just the assumption which we wish to question. It is our conviction that historical and social perspectives, if introduced into these courses, will bring them to life in the colleges even as in the high schools.

The colleges, moreover, provide that further opportunity for special offerings which is now so neglected. No such neglect is exhibited in other traditional fields. It is not assumed, for example, that technical courses in art or in literature are enough: work in the history of these areas is usually given and is often required. The same logic should be applied to science in higher education. Yet, as matters now stand, there are from ten to twenty times as many persons in this country who teach the history of art or of literature as there are who teach the history of science. Such a contrast might have been appropriate in twelfth-century Europe, but would have been a dubious one by the seventeenth century and is nothing short of scandalous in the twentieth. It is time that something was done to overcome this lag in adjusting our educational sights to the realities of the contemporary world.

THE SOCIAL SCIENCES AND THE NATIONAL SCIENCE FOUNDATION

HARRY ALPERT

National Science Foundation

THE National Science Foundation Act (Public Law 507, 81st Congress) creating the National Science Foundation as an independent agency within the Executive Branch of the Federal Government and defining its functions, provides for differential treatment of the natural and social sciences. This differential treatment may be summed up in the statement that the Act is mandatory with respect to the natural sciences specifically enumerated therein, but is only permissive with respect to the social sciences. The explanation of this distinction is found in the legislative history of the Act.

This legislative history, particularly as it relates to the social sciences, has been told in some detail elsewhere. It need not be repeated here. Suffice it to say that in the final version of the Act, the Congress accepted, with respect to the social sciences, the "permissive but not mandatory" position put forth by Dr. Vannevar Bush. In the House hearings during the 80th Congress Dr. Bush stated:

> The Federal Government already does a great deal of work in the social sciences of a research nature. Research in the social sciences is very important indeed. We could well do more. . . . I think it would be a mistake for the Foundation to plunge into work in the social sciences without very careful consideration of what parts it would like to cover, what parts it feels can appropriately be handled under Federal auspices in view of their nature. . . . In other words, the legislation should be permissive but not mandatory, so that the Foundation will not be barred from entering into the field, but on the other hand will not be forced into it until it has given it the study that the subject deserves.

In describing the research support and fellowship and scholarship programs of the Foundation, the Act uses the phrase "and other sciences." The legislative history of the Act indicates that this phrase was clearly intended to enable the Foundation to support social science research when and if it was deemed desirable to do so. A study by William A. W. Krebs, Jr., former General Counsel of the National Science Foundation reaches the conclusion that:

> It is quite clear that the Foundation has authority to make both research grants and fellowship awards in the social sciences. However, the legislative history of the Act indicates that Congress intended the Foundation to exercise a fair amount of restraint in the use of this authority.

Committee reports indicate that language in the Act was so phrased "as to permit the Foundation to explore the needs of the social sciences and to take appropriate action."

In sum, then, the weight of legal and other evidence supports the view that the National Science Foundation *may* pursue five lines of activities relative to the social sciences:

1. Study the status of the social sciences and explore their needs;
2. Study the impact of scientific research on industrial development and general welfare, as provided in Section 3(*a*)(2) of the Act;
3. Undertake social science research activities in the area of scientific and technical manpower;
4. Extend the research grant and fellowship programs and other activities in support of science to the social sciences when and if it is deemed appropriate to do so;
5. Undertake, in relation to the development and encouragement of the pursuit of a national science policy, social science studies and surveys in support of science, including analyses of the sciences viewed as human social activities.

Legal considerations thus define a fairly broad permissive area in which the Foundation may undertake social science studies and support social science research.

In the light of these and other considerations, and in the spirit of Dr. Bush's suggestion that the Foundation should allow an opportunity for effective integration and partnership between the natural and social sciences, but only after careful study of the problem, the National Science Foundation undertook, in March, 1953, a systematic and continuing study of the present sci-

entific status of the social sciences and of the role of the National Science Foundation with respect to social science research.

As a result of this study, the Foundation has been experimenting with a limited program of support of the social sciences. This program was approved last August by the National Science Board. Four criteria provide the framework for its development. They are: (1) the criterion of science, that is, the identification, within the social science disciplines, of those areas characterized by the application of the methods and logic of science; (2) the criterion of national interest, namely, the assignment of highest priority to social science activities directly related to the responsibilities of the Federal Government with respect to national welfare and national defense; (3) the criterion of convergence of the natural sciences and the social sciences; and (4) the criterion of basic research.

As currently conceived, the National Science Foundation's program in the social sciences includes or will include the following activities: (*a*) continued study of the status and needs of the social sciences and of the role of the Foundation and the Federal Government generally with respect to social science research; (*b*) a modest, experimental program of research support of basic scientific studies of an interdisciplinary nature in the areas of convergence of the natural and social sciences, including, beginning in fiscal year 1956, basic research in social psychology; (*c*) extension of the fellowship program, beginning in academic year 1956–57, to support the training of a limited number of predoctoral and postdoctoral students in the areas of convergence of the natural and social sciences, including the history and philosophy of science; (*d*) possible extension of the register activities of the Foundation to include such groups as anthropologists, statisticians, and area specialists by virtue of their special contributions to the mobilization needs of the nation; and (*e*) a limited program of support of fundamental research in the history, philosophy, and sociology of science.

This last program is included because it is generally agreed that studies in the history and philosophy of science have contributed greatly to a better understanding of science as a logical and empirical system and to clarification of the factors, both external and internal, which promote progress in the sciences. Studies in the sociology of science have added to our knowledge of what the National Science Foundation Act describes as "the impact of scientific research upon industrial development and upon the general welfare."

The Foundation has already undertaken some activities along these lines. Six research projects, one conference, and grants for international travel have been supported. The National Science Foundation fellowship program entertains applications in the history and philosophy of science from scholars with backgrounds in the natural sciences.

We are assembled here at this time to give systematic consideration to the present status and research needs of these fields.

It is anticipated that experience over the next few years with the type of limited social science program described above, developing in intimate relationship with the natural sciences, will provide sound guidelines to the National Science Foundation for consideration of appropriate next steps in achieving that effective integration of the natural and social sciences which will enhance the contribution of all the sciences to the nation's health, prosperity, welfare, and defense.

PRESENT STATUS AND NEEDS OF THE PHILOSOPHY OF SCIENCE

HENRY MARGENAU

Yale University

ONE of the primary needs of the philosophy of science is simply recognition. Work in the very important tasks of constructing the philosophical theories to explain and integrate modern scientific advances has been neglected. The field has lacked support and personnel. It would be fortunate for philosophy of science as a discipline if a disinterested and powerful organization were to lend it the moral and financial support necessary to elevate that subject from the doldrums of vague generalities and enable it to fulfill its proper role.

I shall speak briefly on three points: (1) on the need our entire culture has for philosophy of science as an activity, (2) on some particular requirements to be met if that activity is to be successful, and (3) I shall touch upon some technical problems that arise. My views are limited because of my own special background and interests, and I hope that the other conference participants will amplify and broaden my comments.

A. GENERAL COMMENTS

The present state of science provides direct evidence for the importance of philosophy. Science today is fragmented; specialization has progressed to such a high degree that disintegration has set in. This is a real social problem, one that affects our entire culture as well as our science.

Clearly, there is a need to pull together the myriad specialties, not only for conceptual solidarity, but also to escape an increasing hazard of autocratic decree as to what shall be done in the sciences. There is grave danger that political decisions, partisan influences, and "fashions" may motivate research and overrule objective scientific considerations. Such dangers can be combated only by an awareness on the part of scientists of large ideal issues that link and integrate the sciences, and by concerted action of the scientific community regardless of specialization.

I am by no means certain that mere moral indignation at the measures by which dictators have throttled science is a reasonable or indeed a prudent attitude for us to take. For these measures did represent an expedient, albeit a short-range expedient, for the conceptual unification of science; they were an answer to a real problem that exists for us as it does for others. True, we do not like Hitler's or Stalin's answers. But this should not make us somnolent about the problem and its urgency. The solution lies for us in the effort to induce, among specialists, a spontaneous concern for philosophic unity, a wider view, a bond of thought.

Doubtless, all human progress takes its inception (though it never reaches its fulfillment) in specific discoveries. Such discoveries are usually made in those disciplines which, because of their rigid and orderly thought structure, are called sciences. After this beginning, a dual process sets in: one phase tends toward broad application, toward the invention of new comforts and of means of construction or destruction; this phase is designed to affect our external conditions of life. The other, too frequently forgotten, works its way through philosophy, where it fashions ideals and morals, and thence into the discipline of education, where it attains the power to mold our future, national as well as individual.

A society attains balance and stability only if the two phases are in proper equilibrium, as a survey of cultural history shows.

In the past, what measure of stability was present in societies owed its existence to the slowness of both phases, that of technological application, and that of cultural digestion of basic discoveries. For example, gunpowder was discovered in Europe during the twelfth century, used in warfare during the fourteenth. Likewise, during the Middle Ages, centuries elapsed between the time of great discoveries and their philosophical and educational amalgamation.

Today, the process of technological development has been vastly speeded: ten years saw the conversion of a basic discovery into the deadliest of weapons. Yet, philosophers are still groping for the basic meaning of it all, and educators, though ready with their gear for transforming breathless and unharnessed science into something socially and morally significant, are left to do an impossible task. Here, too, speed is essential.

Thus the lesson for education is clear; the

processes whereby philosophical concepts become part of science teaching must be speeded up. The greatest obstacle toward this goal seems to lie at present in the unphilosophical attitude of many teachers of science. For at present, the teaching of science is on a purely factual basis; students are expected and forced to absorb a compendium of data and techniques, the issues of philosophy and history being largely forgotten. This unfortunate practice has had deleterious results. First, students have become bored with facts and their interest in the subject matter itself is significantly waning. Secondly, this pedagogy results in poorly trained scientists—technicians who have no understanding of the philosophical and historical roots and the pervading concepts of their specialty. Under present conditions there is little opportunity for introducing courses in the history and philosophy into the crowded curricula of science students. Hence emerges the importance of history and philosophy as ingredients in the teaching of the sciences themselves. If science teachers were sufficiently knowledgeable in these areas, they should be able to enliven their teaching by references to philosophical and historical matters, and by the same token they would give students a proper perspective and perhaps stimulate their interest to pursue such studies further.

B. SPECIFIC NEEDS

Aside from these general advantages which philosophic and historic interest and knowledge do in fact convey to the teacher of science, there lies in this approach a specific virtue which I should like to emphasize. Much has been said about the conflict between science and the humanities or the liberal arts. There is no root in history for this dichotomy, for science has its beginnings as a kind of philosophy. And if the term liberal is interpreted in the sense of liberating from prejudice, want, fear, and bondage to nature, then there is no art more liberating than science itself. Study and understanding of the philosophy of science can humanize by introducing historical and philosophical concepts into the body of basic data, thus forging links between science and history—between science and the arts. In this way the existing cleavage can be minimized and efforts begun to unify the fields once more.

Who is to do this? It seems to me that the task of interpretation can be performed best by scientists who have learned enough philosophy to translate their basic discipline into terms which are comprehensible to men in other fields. This is an exceedingly important task calling for scientists with philosophic circumspection. Yet it is often regarded as a menial chore, a matter of popularization, something below the dignity of the research scientist. To him it is far more fascinating to speculate mathematically about "world lines going backwards in time" than to explain the meaning of such terms to the eager workers in philosophy who, except for such efforts of translation, will be left in the mist for decades as to the precise significance of such phrases. I take it to be one of the primary needs in the present context that the basic concepts of science be interpreted in philosophic terms. There is a wide gulf between present scientific discoveries and what philosophers conceive them to be. The scientists who are most intimately acquainted with the discoveries usually lack the training to translate the concepts in terms understandable to philosophers. As a result, philosophical doctrines spring up containing erroneous views of nature. And this circumstance is in part responsible for the retardation of the cultural strand of that dual process launched by a scientific discovery of which I spoke above.

Ignorance of elementary philosophy has led to a widespread belief on the part of scientists and of the general public that science is nothing but an accumulation of certified or certifiable facts. This in turn has produced a popular attitude of derogation toward theory and a belief, especially prevalent among students in the humanities, that theories somehow falsify the facts. The correct attitude, namely, that theories inspire facts with significance and meaning, cannot easily be seen without some training in philosophy. It is not difficult to make evident such misconceptions together with the regrettable effects they have produced. Clearly, it is one of the tasks of philosophy of science to correct them.

There are further problems beyond the correction of such misconceptions—tasks which have a more positive aim. One is to work toward the unity of the sciences themselves. In this connection it is not enough to call attention to superficial features of similarity among different branches of knowledge. True, this needs to be done, but more important is the development and dispersal of knowledge concerning the *fundamental concepts* underlying science. This undertaking requires careful and thorough examination of the *method* and *procedures* of science.

We need also to understand problems which affect science but which are not in themselves

wholly empirical. Ontological, metaphysical, and cultural considerations that go into the making of science should be exposed to view. An effort must be made to separate, in any given science, what is axiomatic from what is empirically given.

C. PROBLEMS IN PHILOSOPHY OF PHYSICS

As a physicist, let me touch upon some special problems arising in the philosophical study of modern physics, in the hope of stimulating some discussion.

1. The whole of modern quantum mechanics suffers from confusion regarding the meaning of measurement. There are several conflicting theories, some of them wholly contradictory, often thrown together without discrimination in a single research article or in a single text. It is my view that the significance and the limitations of quantum theory will not be clearly established until the contradictions are expunged from the meaning of the term measurement.

2. The causal interpretation of quantum theory is a matter of interest in contemporary physics. Here is an issue that is truly philosophical. All current theories lead essentially to the same observations and the same predictions, although they differ in philosophical detail. In this area physicists are dealing with unaccustomed matters that require some philosophical knowledge and sophistication rather than physical techniques. Truly, collaboration is essential and is welcome at this crucial point of modern doctrine.

3. Elsewhere I have called attention to the distinction between "possessed" and "latent" observables in modern physics. The psychologist uses, in his assignment of attributes to human objects, qualities like anger, equanimity, etc., qualities that are only intermittently present and have no existence at certain times. Is this what the physicist is doing when he speaks of observables as "emerging" at the instant a measurement is performed? This question is evidently related to the first of this list; it is fascinating but has not been studied with the care it deserves.

4. The philosophical implications of the uncertainty principle are not altogether clear. There is a gap in our understanding and proper support of the philosophy of physics would operate to narrow this gap.

D. RECOMMENDATIONS

The Steering Committee of this Conference has outlined some questions for discussion. I should like to close my remarks by listing the relevant questions and commenting briefly upon them.

Question 1. *What is going on in the field with respect to research and training?*

Some successful work is being pursued in the logic of explanation, and this deserves encouragement. There are sporadic attempts to unravel axioms that underlie special disciplines such as mechanics or relativity or quantum theory. This work is being done mainly by logicians whose interest in modern applications is often slight. A few papers here and there deal with interpretations of modern physical theory in philosophic terms. But the important problems mentioned in Section C, do not seem to be under consideration at the present time.

Question 2. *What are the sources of financial support in this area?*

There are none. Universities will not support work in this area because it falls between established departments of learning. The barriers between departments and disciplines in almost all American universities are unsurmountable. For this reason, very few young men are coming up in the field of philosophy of science at this time. All this is in utter contrast with the noteworthy fact that the most distinguished of our natural scientists become, and have always become, philosophers when they mature. Men like Einstein, Schrödinger, Heisenberg, De Broglie, Bridgman, and innumerable others have written earnestly and eloquently about philosophical issues. Characteristically, philosophers untrained in science frequently ignore their writings, saying that what matters is what physicists do, not what they say. This bespeaks a situation which I find deplorable. It suggests that we urgently need to train a generation of younger men, both scientists and philosophers, who are equipped with the disposition and the facility for heeding the mature wisdom of successful scientific men.

Question 3. *What personnel is available for research and teaching in these fields?*

The personnel in the field are too few and too scattered. They seem to drift into the philosophy of science by chance and have a wide variety of training. In general men tend to shun philosophy of science as a choice of major interest because it lacks support. Hence, too, arises the impression

that it is an inferior sort of discipline which only people inept at science are meant to cultivate. With recognition, and with proper support all these difficulties might vanish overnight.

Question 4. *How can research in this field be of aid to science?*

The philosophy of science, it seems to me, is a part of science. The question, therefore, is perhaps not very aptly worded; for, as a component of science itself, the philosophy of science deserves and requires aid for its own sake in the same way as any other specialized scientific activity. This is not yet fully recognized. Noteworthy in this connection is the reluctance of physical science journals in this country to publish work on fundamental questions involving philosophy of science. Journals in Europe have long been aware of the importance of articles of this kind and have accepted them for publication along with so-called technical contributions. If the National Science Foundation should make a gesture recognizing the importance and the dignity of scientific philosophy by according it a place within the framework of the Foundation, this unfortunate condition with respect to media of publication and other handicaps might very well disappear.

Question 5. *What role can the National Science Foundation play in support of research and education in this field?*

Which of the following programs of the National Science Foundation might be considered in this connection?

Research support,
Graduate fellowships,
International travel,
Conferences in support of science,
Summer seminars,
Training of science teachers,
Exchange of scientific information.

The National Science Foundation can help through all the functions listed. We must, however, consider priority of needs. At the present time the manpower problem is an extremely urgent one; there are not nearly enough people in the field. This situation can be remedied most directly through fellowships and research support.

A program aimed at increasing the number of scholars active in this area would, as a later consequence, improve the science teaching in colleges and secondary schools. But a more immediate effect of this sort could be achieved by arranging for summer seminars, where the participants are science teachers and the instructors those few individuals who now profess philosophy of science as their specialty. Highest priority at the moment, however, must be assigned to enlarging the pool of manpower, and anything that the National Science Foundation can do toward this end will be extremely valuable.

PRESENT STATUS AND NEEDS OF THE SOCIOLOGY OF SCIENCE

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AMONG the social sciences, sociology is still one of the smaller fields of professional specialization, as measured roughly by number of members of the professional associations in the several different areas. Economics, political science, and psychology are all larger, and so also is history, if we may include it in part among the social sciences. Perhaps only anthropology has fewer professional specialists in its ranks. Within sociology, moreover, the special field of the sociology of science is one of the smallest of those taken as a province of specialization. Such fields of specialization as social stratification, industrial sociology, family sociology, and a few others are cultivated by many more sociologists than is the sociology of science, as measured roughly by scholarly publications such as books and articles. Very few sociologists have ever spent much of their time on the sociology of science, perhaps chiefly because very few sociologists have been trained in the technical substance of the natural or biological sciences.

Nevertheless, though the sociology of science has always been a relatively small specialty, it has been extremely fortunate in the quality of those who have done much work in the field. No other field of sociology, large or small, can include among its devotees more distinguished a trio than W. F. Ogburn, Talcott Parsons, and Robert K. Merton. This means that the sociology of science, though cultivated by very few, has great prestige in sociology as a whole. This prestige could be used to attract more young sociologists to this specialty. Moreover, because of the excellence of the work already done in this field, there are now available both theoretical propositions and models of research that can form excellent foundations for future work. The sociology of science has made a very good beginning.

Unfortunately, there is not now a single professor in any one of the major graduate departments of sociology who is devoting the largest part of his research and teaching time to the sociology of science. Professor Ogburn, now retired, no longer has any students, though he is still prolific of books and articles on the reciprocal relations between technology and other social factors, especially in so far as these relations bear on the problem of social change. Professor Parsons is now primarily engaged in developing a generalized system of sociological analysis, but he continues to direct some research in the sociology of the professions, a field in which he also teaches a course. This field of the sociology of the professions overlaps in some measure with the sociology of science, as, for example, in a recent dissertation by one of Parsons' students, Dr. Renee Fox. Dr. Fox's research investigated some of the moral and emotional problems of the research physician and some of the typical modes of adjustment to the strains resulting from these problems. Professor Merton is also now devoting the major share of his research work to the sociology of the professions. He and Professor W. J. Goode are now completing a casebook in the sociology of the professions for the Russell Sage Foundation. Professor Merton is also directing, under the sponsorship of the Commonwealth Foundation, a research investigation into the "socialization" of the medical student, that is, into the process by which the medical student acquires the norms and sentiments, as well as the ideas and techniques, of the mature medical practitioner. The sociology of the professions has an important overlap with the sociology of science in so far as the profession of scientific research has certain sociological characteristics in common with the other professions. It overlaps also in so far as studies into the applied science professions, such as medicine or engineering, are the specific objects of studies now being made. It would, of course, be most desirable to have more investigations made directly of the profession of research science itself. For example, a careful study of the relations between individual and team research as these actually operate in the natural and biological sciences is needed. (For some interesting, unsystematic analysis of this problem in the social or "behavioral" sciences, see the Report by a Faculty Committee, *The Behavioral Sciences at Harvard*, pp. 246 ff.) We do not now have a single excellent empirical study of a scientific research lab-

oratory and of the part played in such a laboratory by individuals and teams of researchers. There are many other important aspects of professional scientific research about which we lack reliable knowledge.

The sociology of science is, fortunately, in a somewhat better condition than the foregoing account has described it, if we include all the studies of the social aspects of science that have not been done by professional sociologists but that still satisfy the best theoretical *and* empirical standards for sociological research in this field. We may mention only a few examples. Professor R. H. Knapp, a psychologist, and H. B. Goodrich, a biologist, have published an outstanding book, *Origins of U. S. Scientists* (University of Chicago Press, 1952), on the social class, economic, and religious origins of American natural scientists. This book also tells us a great deal about the "socialization" of these scientists, in the sense of "socialization" defined above. We learn a good deal, for example, about the importance of inspired teaching on the undergraduate level for the recruitment of professional scientists. Professor Knapp and a collaborator, Professor Greenbaum, have added to our knowledge also with another book, *The Younger American Scholar* (University of Chicago Press, 1953), which treats other scholarly fields as well as science. Professor C. C. Gillispie of Princeton University, an historian, in his book, *Genesis and Geology* (Harvard University Press, 1951), has made an excellent analysis of the relations between religion and science in England in the first half of the nineteenth century, before Darwin. This book has much else of value in it, about the class origins of scientists, the problem of competing schools in science, and the consequences and problems of the popularization of science. One last example. Professor Donald Fleming, another historian, is about to begin a study of the effects of communism on recent American science, under the sponsorship of the Fund for the Republic of the Ford Foundation. Such a study will have sociological aspects and may add valuable knowledge to the sociology of science.

There are vital implications for future training and research programs in the fact that some historians and natural scientists are doing work that is essentially the same as professional sociologists might do, with respect both to theoretical problems and substantive materials. The most important implication is that sociologists and others should have ways and means of collaborating both on research and on training programs, wherever a sociologist and some other scholar find it congenial and convenient to work or teach together. Whenever such collaboration arises spontaneously, which is one of the best ways for it to occur, then there should be some means available for subsidizing it. It would be most desirable also to have means available whereby an historian, for example, could improve his training in sociology, if he so wished, and whereby a sociologist might learn more about the techniques of historical research. Historians in search of sociological training will, of course, for the present have to piece out their training as best they can, as long as there is no center for work in the sociology of science. Some personal help is still available to such historians, however. For example, a student of Professor C. Vann Woodward, the American historian at Johns Hopkins University, is now working part-time with Merton at Columbia University on a sociological history of the American engineering profession in the nineteenth century.

So much, all too briefly, for what is going on in the sociology of science with respect to research and teaching. What about the sources of financial support in this area? The chief sources are the same as for all fields of sociology: individual self-subsidy, in the form of university salary; small university subsidies in the form of research grants-in-aid; larger subsidies from foundations, as in the studies mentioned above by Merton on the professions and Fleming on communism in science; and some important subsidies from the United States Government. Among these Government-sponsored studies have been the National Resources Planning Board's reports in the 1930's, on industrial and business research and on *Technological Trends and National Policy*, the latter study written by Professor Ogburn and a group of scholars under his direction. In the post-war period, the Government has subsidized the reports of the President's Scientific Research Board on the federal research program, manpower for research, the administration of research, and medical research. Government subsidy has been forthcoming upon the recognition of the importance for public policy of some one or more of the social consequences of science. In the 1930's, the Government was chiefly concerned with the economic and social consequences of technological innovation and industrial research. In the post-war period, however, the Government has been concerned with the social aspects of fundamental as well as applied scientific research. It is now

clear to all that fundamental research has important indirect social consequences, through applied research, and sometimes even direct consequences as well. The sociology of science should include studies of both fundamental and applied research, in the past as well as at the present time.

How can the sociology of science be of aid to science? This question occurs inevitably to sociologists who have a sense of social responsibility for their research as well as some scholarly delight in that work for its own sake. A proper answer to the question would, of course, take much more time than we have here. I have tried to give the materials for an inclusive and detailed answer in my book, *Science and The Social Order* (Glencoe, Ill., The Free Press, 1952). I can only be brief and elliptical here.

It is necessary first to state the basic premise of the sociology of science, namely, that science is a social activity, and therefore as much subject to social scientific investigation, as any other human activity. On this premise, the broadest answer to the question, how can sociology of science be of aid to science? is this: *the sociology of science seeks to establish as specifically and precisely as possible the social conditions under which science makes maximal progress.* Since there are a great many different social factors that interact with science in society to condition its progress, such a broad statement has to be broken down into a large number of questions about which the sociology of science seeks to establish valid propositions. Here are some of these questions. Note that they are not stated in any necessary order of importance. The various social factors mentioned all affect science directly or indirectly, and the matter of influence is an empirical one to be decided in every particular concrete instance. To most of these questions we already have some kind of rough answer, but for all of them we could use more scientifically satisfactory answers.

To repeat, here are some important questions about science and society: What values and attitudes among the members of a society furnish approval of and positive support for the activities of scientists? How are these values and attitudes created? How are they maintained when they are already in existence? Given attitudes favorable to science, how are scientists themselves recruited? What are their social class, their economic, their religious origins? How are scientists "socialized," that is, how are the appropriate norms and values of scientific research, as well as scientific knowledge itself, instilled in them? How should scientific research be organized? How much individual research? For what problems? How much team research? For what problems? What property rights in his ideas should an individual scientist have? What are the advantages and disadvantages for science of different types of political system? Do all political systems have a mixture of advantages and disadvantages? How can published and personal communication among scientists be optimally arranged? What religious and secular ideologies are most compatible with the development of science? What are the sources of economic support for science? What are the proper proportions of fundamental and applied scientific research? Are these proportions different at different times? How can the different sciences best stimulate one another to progress? What are the best kinds of support that the universities, the small colleges, industry, the Government, and the foundations can give to contemporary science? What are the responsibilities of science to predict and control its discoveries, meaning by "responsibilities" those moral *and* rational considerations that affect the relations between scientists and other social groups in society?

These are some important questions, it will be obvious to all of us. Because sociology is still a relatively new discipline, these questions overlap one another and they are not always operationally amenable to precise hypothesizing and testing. Yet, since they are important questions, we need better answers to them, for then we shall know more about the social conditions under which science advances. We may say, in summary, that the sociology of science can aid science by working for the improvement of our knowledge about the questions we have had time only to list.

Our next concern is, how can the sociology of science be of aid to the educational process? In so far as the sociology of science can specify the conditions under which science can make maximal progress, it can also specify the conditions that hinder such progress. Knowledge of both kinds can be of use not merely to working scientists but also to two other groups currently in the educational process. The first group consists of those students majoring in science and intending to become professional research scientists, pure or applied. We should include here, that is, not only students in liberal arts colleges and universities but also those in the engineering colleges and graduate schools. The second group

consists of all those other college and university students who will not themselves do scientific research but whose behavior and attitudes in contemporary society, especially with regard to science itself, will be fundamentally affected by their knowledge about the social aspects of science. Both groups of students, the future scientists and the others, would be profited by learning something of the sociology of science. Scientists-in-training would be helped in so far as the sociology of science would be of use to them both as scientists and as citizens. Others would be helped in so far as the sociology of science would make them better citizens in what is, in fundamental respects, a "scientific" society. Of course, sociology of science should be taught to the two different groups in different ways. For the scientists-in-training, there must be made a continuous and responsible effort to relate sociology of science *as directly as possible* to their substantive training in science. We all learn better, especially at the beginning, if more generalized and abstract knowledge is related directly to our concrete, day-to-day working activities. Ideally, there should be a sociology of science applied to physics, a sociology of science applied to biology, and perhaps even to more specialized areas within each of these broad sciences. Of course, the ideal is impossible of enactment just now, but the principle is important, that generalized knowledge from another field be brought to bear as concretely and directly as possible upon the field of activity it is meant to influence. For the students who will not become professional scientists, the sociology of science may be taught somewhat more systematically, somewhat more abstractly, perhaps, though always even here with as many concrete and comprehensible examples as possible. Perhaps it would be best to do what some of the General Education courses in science at Harvard College have already succeeded in doing. Some of these courses combine an introduction to the technical substance of a science, say, physics or chemistry or biology, with an introduction to some of the philosophy and sociology of science. It is possible, however, if I may refer to a course in the sociology of science I once taught to advanced undergraduates at Smith College, to teach sociology of science without very much technical scientific content. This is probably the least desirable kind of course, but it has great virtues, none the less, for those students who are not interested in the technical substance of the various scientific subjects.

All apart from the aid it can give to science in the educational process for pre-professional and other students by showing the social aspects of physical and biological science, the sociology of science has still another virtue for the training of both these groups. This is the virtue that arises from having all students see that social science is in principle as possible and desirable as the science of any other class of empirical phenomena. For the welfare of our society as a whole and therefore for the natural sciences in that society, it is desirable not only that social science actually make progress but that natural scientists and others come to feel that social science exists in fact and should be improved. Thus the sociology of science can be of aid in the educational process not merely to the natural sciences but to science defined in the most inclusive possible way.

Finally, what are the research and training needs in the sociology of science and what role can the National Science Foundation play in support of research and education in this field? The primary need at the present time, probably, is for the training of more people for research work in the sociology of science. Such training could occur either at the graduate or the post-graduate levels. At the graduate levels, sociologists- or historians-in-training might be attracted to the sociology of science in greater numbers if more graduate fellowships were available. The number of people attracted to a specialized field of research is no simple product of the number of fellowships in that field, to be sure, yet fellowship aid might occasionally tip the balance in a decision between sociology of science and some other specialty. Young historians might be encouraged by fellowship aid to take more training in sociology in order to fit themselves for a more sociological approach to historical materials about science. Post-graduate fellowships might also, in somewhat smaller measure, accomplish the same purposes, though usually the decision made in graduate school about field of specialization persists throughout a scientific career. Sometimes, however, a post-graduate fellowship can attract back into research a well-trained scholar who is now primarily engaged in teaching.

Fellowship aid, then, at various levels, is probably the primary way in which the National Science Foundation could at this time aid the sociology of science. There are, however, other ways it could be of aid. Some research subsidy, either to practicing researchers or in the advanced

stages of training, could be of great assistance. Graduate students may be all the more willing to commit themselves to a sociological specialty if not only fellowship aid but research support for doctoral dissertation is available. At the more advanced stages of the professional career, of course, research support is invaluable, sometimes even in relatively small amounts. Apart from direct fellowship and research support, the National Science Foundation program of subsidizing summer seminars might have valuable research and training functions. Such summer seminars have been profitably sponsored for various fields of specialization in the social sciences by the Social Science Research Council, and the procedure seems as applicable to either general or specific subjects in the sociology of science as to any other sociological specialty. Finally, also valuable occasionally is support of international travel to sociological conferences at which papers on the sociology of science are to be read. In all these several ways, through its established programs of aid to fundamental scientific research, the National Science Foundation could now give essential support to training and research in the sociology of science.

PRESENT STATUS AND NEEDS OF THE HISTORY OF SCIENCE

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THE history of science is a specialized form of history. In it are studied the genesis, growth, and influence of scientific ideas, techniques, and knowledge—both as to themselves and in relation to the main streams of culture and material civilization. This subject has special values for three groups: the sciences, the social sciences, and the humanities. The work that is done in the history of science has come from scholars of different backgrounds, some of whom have been trained in the sciences, others in the social sciences, and others in the humanities. The work in this field has as its primary aim to illuminate a significant thread of our civilization, one that, curiously enough, has been neglected to a large degree.

In considering the values of the history of science an analogy with the sciences may be in order, because there is a natural division which is similar to that between "pure" and "applied" science. This analogy may be particularly helpful in a general discussion of research in the history of science because most scholars and scientists are not primarily concerned with the history of science as such. Philosophers and sociologists, in particular, are very apt to be interested in the history of science only to the extent that it supplies information, perspectives, or points of view that are of use to them in their own work; the uses to which they put the history of science may, therefore, be compared to an area of "applied" science. For the man who deals in the main with applications of the history of science, important fundamental studies—such as the deciphering and interpretation of texts of Babylonian astronomy, or the collation of the manuscript versions of Archimedes or Euclid used in the Latin Middle Ages, or an examination of the quality of translations of Greek medical works into Arabic in the early Middle Ages—may seem to be valuable only from an antiquarian point of view. Yet the historian of science, whose focus of attention is more likely to be centered in the "pure" end of the spectrum than the "applied," will particularly esteem such research. For him it reveals valuable information about the stream of scientific activity, i.e., about the interrelation of the continual and the novel, which constitutes the essence of history. Studies of Babylonian astronomy push back the beginnings of exact mathematico-physical science to a time earlier than, until quite recently, we had any idea. Knowledge of the versions of Archimedes or Euclid available in the Latin Middle Ages seems especially noteworthy to the historian because it gives him information concerning the state of science preparatory to the notable advances which prepared the way for Galileo and Newton. Studies on Islamic science and the role of Islam in transmitting the science of antiquity to the Middle Ages (with variations and improvements) are of interest to the historian of science because they fill the gap in the continuity between ancient and medieval-to-modern science.

Much of the best work in the sociology of science has been allied to the history of science. It is noteworthy that the major recent monograph in the sociology of science, which has become a modern classic, is R. K. Merton's analysis of science, technology and society in seventeenth-century England. Among other recent authors who have used the history of science in sociological discussions are the late Edgar Zilsel and Bernard Barber. These authors have worked in the "applied" end of the spectrum of the history of science because their aim was primarily to advance sociology, to increase our understanding of the interactions between science and its social environment or of the sociological aspects of science itself. In other words, they used the materials and techniques of the history of science for purposes of immediate application in another discipline.[2]

[1] In consultation with Marshall Clagett, Donald Fleming, John F. Fulton, Henry Guerlac, Richard H. Shryock, and Conway Zirkle.

[2] I am grateful to Robert K. Merton for clarifying the issue as to whether my use of "pure" and "applied" is only metaphorical. In a sense, one of the major functions of the history of science as a discipline is to illuminate other fields of inquiry: the sciences, the humanities, and the social sciences. It might, therefore, be argued that all important work in the history of science may serve as a source of applications for other scholars. But here the analogy with the sciences is quite exact

At the same "applied" end of the spectrum there are historico-philosophical investigations, some of which have greater permanent value than others for the historian. Certainly noteworthy in this regard is the fact that two extremely influential philosophers of science were concerned with the historical development of the sciences, Ernst Mach and Pierre Duhem, although Duhem largely found confirmation for his already formed philosophical point of view in history. Poincaré, the third influential philosopher of the day, also applauded history. Auguste Comte, founder of the positivistic philosophy, was an advocate of the need of studying the history of science. Historians of science themselves do not disdain the "applied" end of the spectrum and many of them have produced important works which, so to speak, partake of both aspects. R. Hall's investigation of ballistics and dynamics in the sixteenth and seventeenth centuries is an example of the middle ground in tracing the history of the arts of ballistics and technological needs of society in relation to advances in pure science.

Yet historians are continually appalled by the errors of fact in the use of the history of science in all too many books and articles that treat of the philosophy and sociology of science, just as—I suppose—philosophers and sociologists may find many historians naive from their special points of view. Such errors may often be excused by the inadequacy of the literature of the history of science. Yet one may legitimately question the merits of an historico-philosophical or historico-sociological work on science if the facts are wrong and if the author ignores the fruits of research in the history of the subject he explores. It would seem to me to be easily demonstrable that sound work in the philosophy or sociology of science would require a knowledge of at least one branch of science at the research or graduate level and a deeper knowledge of the history of science than an elementary survey course.

At the "applied" end of the spectrum, the history of science has a special function in relation to science itself. Educators generally agree on the value of using historical materials in teaching science to the non-scientist, as a means of relating his science education to the main streams of our civilization by indicating points of contact between science and literature, science and theology, science and fine arts, science and philosophy, political thought, and the like. The success of these programs in "general education" requires case histories of scientific development which must be accurate and well informed if they are to be of real service. Thus special demands are placed on the professional historians of science, at least to aid science teachers to locate and interpret this kind of material and to provide critical controls. Another notable application of the history of science in education deals with training engineers who will be freer of the "slide rule" mentality than heretofore. The success of the course in "Science in Western Civilization," pioneered by Henry Guerlac at Cornell, as a means of relating humanistic and technical study is heartening, and attention may be called to the new humanistic programs at M. I. T.

I believe it to be true that the study of the history of science has special virtues as regards the progress of science itself. The issue is not yet decided as to whether America has become or can be a great scientific nation. There is no question of America having made fantastic achievements in all the realms of the application of science. But it certainly is a fact that during the last 150 years the fecund leading ideas and general theories by which science has made its greatest progress

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because advances in "pure" or "fundamental" or "basic" science are always potential sources of applications for industry, agriculture, medicine, and the arts in general. Furthermore, the sciences are always apt to be "arts" to one another; for example, "pure" physics uncovered the wave properties of electrons, a phenomenon that has produced a valuable tool of research for "pure" biology in the electron-microscope.

The spectrum of "pure" and "applied" science has been compared to the electromagnetic spectrum: continuous, without sharp demarcations. This would also appear to be true of "pure" and "applied" research in the history of science. Finally, it is now a common phenomenon in "applied" science that research inaugurated for a specific practical end may produce, at the same time as the useful result, a contribution to fundamental knowledge. So, too, research in "applied" history of science may often yield something that will be of equal value to the historian of science and the scholars who are more concerned with the application. For example, R. K. Merton's classic study is esteemed by all historians of modern science just as much as by sociologists.

The distinction between "pure" and "applied" seems of particular value in a discussion of research needs because a judgment of the worth of a project by a non-professional historian of science is apt to be qualified by the possible points of contacts he may see between the project and the other kinds of work, notably his own. Yet, just as in science itself, the values of research in the history of science should not be limited by the envisaged possibility of use by other disciplines. Even from the "applied" point of view, who can tell which research will have the greatest "practical" value?

have not originated in our country in anything like the proportion for which we hope. We do not as yet know much about the conditions under which ideas in science are produced, and here is an important field of research in "applied" history of science. I believe there may be some merit in the view that the production of great scientific ideas can be stimulated by inculcating a general respect for ideas in our budding scientists. The training of scientists might be immeasurably improved if they were given some background in the history of their subject and were made to see that science is more than a collection of facts and special techniques, and that the role of the creative imagination has always been paramount.

At the present time it would seem especially necessary for scientists to know something about their historical place in society and the growth of modern culture. Scientists and non-scientists both must recognize that the problems which arise from the interactions of science and society have not originated in the middle of the twentieth century, but have been—in varying degrees—a characteristic feature of the growth of science in modern times. Furthermore, the perspective of the history of scientific ideas can be of immeasurable importance in producing a worth-while critical attitude. It is probably true that a great many of our scientists may have no well thought-out philosophy. Some of them may even be uncertain about the general nature of science or even the particular qualities or attributes of the scientific enterprise. The history of science can be of help here. I have mentioned the examples of Mach and Duhem above and I may perhaps add a note about our distinguished British guest, Professor Dingle, whose historico-philosophical point of view in criticism of recent theories of cosmology and in analysis of the roots of Eddington's philosophy show the importance that this field may assume.

The temptation to support the "applied" end of the spectrum is very strong. An industrial concern would not think twice about expending $50,000 for a history of a subject like pressurized flight, but how difficult it is to find one-tenth that amount to aid the study of the prehistory of the revolution in physics associated with the name of Galileo! It is certainly of major importance to our consideration of present-day problems to have a better understanding of the role of the scientist as a member of the community, seen in historical perspective. An important dimension may be added to our evaluation of the scientific enterprise and of science as a cultural force by studies in the history of science. Considering the vast effects of the applications of science during the last one hundred years on our daily lives, our health, our industry and economy, our social structure, and our political life, there is a crying need to have exact historical information on such topics as the rise of industrial research, the relations between science and medicine, the reactions of science to the demands of warfare and the relations between science and government.

Yet important as such studies are, they must be supplemented and in almost all cases preceded by a central core of reliable knowledge on the development of science at the "pure" end of the spectrum. The great texts of science must be edited and translated. These are the primary tools. The list of works which are unavailable for study in modern critical editions is extraordinary. For example, there is no adequate edition of the greatest of the works of modern science, Newton's *Principia,* in which the reader may find even an index or a table of contents. Many of the great classics are available in languages which are not readily accessible to the average reader, or exist only in rare or difficult-to-obtain older versions. Critical commentaries, biographies, and interpretive monographs are also lacking. We have as yet no editions, for example, of the correspondence of Lavoisier, Newton, Buffon, or Laplace. The same is true of Faraday, Kepler, Clerk Maxwell, and scores of other major scientists. We lack reliable studies of all too many aspects of the growth of ideas, methods and information concerning particular subjects in science in all periods and in many countries and cultural areas.

Finally, there are needed some sound investigations of the institutional development of science. What has been—in different periods, countries or cultural areas—the education, training, and support of scientists? What were the resources available for the support of scientific research and how was the quality and quantity of support related to progress in different areas of scientific endeavor? It is important to know something about the organization of scientific activity and the status of scientific communication and the standards of research at different times and places. If the progress of science is to be made secure, it is necessary to know the conditions under which science has flourished or decayed.

Above all, if we are to face a world in which science and its applications have a dominant role, we must have some perspective on the historical aspects of science as a history-making factor in the collective life of man.

To further the history of science aid must be given on three levels: the training of historians of science, the furtherance of research, and the diffusion of the results so that applications may be made by the many groups described above who wish to use the history of science. At the present time, in the United States, the history of science is taught in many institutions of higher learning, but only a few universities have programs for advanced training, say leading to the Master's or Doctor's degrees. They include Brown, Cornell, Harvard, Johns Hopkins, and Wisconsin. Many of those who work in the history of science are therefore self-trained and have primary teaching obligations and academic affiliations in departments of history, philosophy, literature, or one of the sciences. All too often, therefore, they do not come under regular research budgets. Usually, scientists and scientific organizations consider that the history of science is a part of history and belongs to the humanities or social sciences. The latter groups reply that the history of science is "scientific" or deals with science and should therefore be supported by the sciences—which in their view have all the money today in any case. Hence, special sources of support for the history of science are imperative.

Some of the types of support that might be given by the National Science Foundation to achieve the aims described above are as follows:

(1) Graduate training. It would be helpful to have fellowships to enable graduate students to pursue studies leading to a doctorate in the history of science. The needs here are for subsistence and tuition, traveling fellowships, and small grants to aid research.

(2) Post-doctoral fellowships, specially earmarked for the history of science (same for philosophy and sociology of science). These would be intended to enable men and women who have completed a degree in the sciences, the humanities, or social sciences to follow a year of study at the graduate level so as to learn to develop further the methods and techniques of research in this field as well as some history of science. Many such persons would help diffuse the history of science in their research and teaching and would be able to work in the "applied" area, and some might eventually do valuable work at the "pure" end of the spectrum.

(3) Publication. High on any priority list of any publication needs in the history of science is the support of the preparation and publication of the annual Critical Bibliography of all publications in the field of the history of science and its cultural influences throughout the world.[3] This extremely valuable research tool serves not only historians of science, but science teachers, philosophers and sociologists interested in science, and all who do research in the humanities and the social sciences where the growth and influence of science is relevant.

Many meritorious works in the history of science require grants in aid of publication. Books and articles often demand difficult composition, the preparation of drawings, and costly diagrams or plates. The necessary critical apparatus to scholarly publication increases ordinary publication costs immeasurably.

(4) Research projects. Established historians of science or young men of promise often need funds to travel at home and abroad for short or long-term periods to obtain necessary materials for their research. Funds are also needed for research assistance, secretarial aid, relief from teaching, and direct expenditures for books, instruments, computations, photostats and microfilms, and the like.

(5) History of the National Science Foundation. As the Foundation enters its fifth year, it is hoped that consideration will be given to the eventual writing of its history and a full evaluation of its influence. This will have to include the worth of both the projects it has supported and those it has failed to support. Surely it is not too soon for the Foundation to consult historians of science, at least with respect to the preparation of materials for such a history. Information should be obtained now so that records will be kept in such a way as to be useful to the historian.

In conclusion, I should like to urge once again that in considering programs in the history of science, special caution be given to insure that the great stream of "pure" research be supported, even if it may often seem irrelevant to practical "applied" problems. The seemingly useful or "applied" projects depend for their accuracy and

[3] Thus far 80 such Critical Bibliographies have been published in *Isis*, the quarterly journal of the History of Science Society.

completeness on the extent of the fundamental information available. It goes without saying, therefore, that the worth of all projects and grants in the history of science must be judged by competent historians of science who alone are in the position of being able to see their eventual worth. To the extent that the history of science aids our understanding of science, provides grounds for interpretations of scientific activity by humanists and social scientists, and enables everyone to view the needs of science and the problems of science in relation to society, any worth-while project in this area could be legitimately supported by the National Science Foundation. The only restriction must be, of course, that support be given only to projects of demonstrable merit, and undertaken by students whose promised or fulfilled capabilities are clearly evident.

COMMENTS

HERBERT DINGLE

University of London

DR. MARGENAU has raised so many questions of interest in the philosophy of science that I must resist the temptation to speak on any of them for want of time, and simply relate briefly what we do at University College, London, in this subject. Its main feature is that the philosophy of science is regarded as the philosophy which is implied by scientific practice throughout its history, and the study of the subject is the attempt to express what that is. This distinguishes it on the one hand from the philosophy of science as it is understood by many modern writers who base their conclusions only on the latest developments of science instead of on those essential elements of it which are manifested at all stages of its growth. It distinguishes it also, on the other hand, from the philosophy of science as it is taught in many university departments of philosophy where science is fitted (with more or less distortion) into an independent, pre-conceived philosophy instead of being treated as source material from which the philosophy of science is to be deduced. Such a study of the philosophy of science is possible in the fullest sense only to scientists, who already have considerable experience of scientific practice, so our courses are restricted to students holding a science degree. They have proved very acceptable, and the number of students has risen steadily since the scheme was put into full operation after the last war and is still rising. I would recommend this approach to the subject as one likely to be of value in the United States also.

Reverting for a moment to the nature of the philosophy of science, it should be remembered that historically science is a particular kind of philosophy, and the early seventeenth-century scientists, who started science as we know it today, regarded themselves as philosophers dealing with the traditional problems of philosophy but approaching them in a new way. The gradual separation of science and philosophy would be a useful historical study. The consequences have been regrettable, and I think we should learn once more to look on science as a philosophy.

It seems to me that the association of "the sociology of science," as the subject has been described to us by Dr. Barber, with the history and philosophy of science is a mistake. The association seems to arise from the confusion of science with the scientist. The subject matter of the history of science is science, that of the philosophy of science is science, but that of the "sociology of science" is the scientist. Both the history and the philosophy of science are necessarily dependent on the content of science itself—i.e., on the actual knowledge that the scientist brings to light. For instance, if the theory of evolution or the theory of relativity were found to be so at variance with some new discoveries that it came to be abandoned, both the history and philosophy of science would be profoundly affected, but the "sociology of science" would be quite unaffected because there would be no change in the type of activity of the scientist or in his relation to his social environment. "The sociology of science" seems to me to be a particular science, like the ecology of some type of living creature other than man. It is the study of the relation between the scientist and his social environment, and is on all fours with the study of the relation between, say, ants or bees or elephants with their particular environments.

I would emphasize that this in no degree detracts from its importance which is beyond measure. But it does suggest that this subject should not be grouped together with quite different kinds of study such as the history and the philosophy of science, which take the actual content of scientific knowledge for their province.

The study of the history of science, as discussed by Dr. Cohen, has the same justification as that of history in general, and needs no special plea for its encouragement. It has, however, an additional importance in that the history of science is essentially a part of its own subject—science itself—in a way which, I think, is true of no other discipline. An outstanding characteristic of the philosophy which is science is that it is progressive, each advance depending on and being

validated by what has gone before. In any modern scientific paper there are references to previous papers, they themselves contain certain similar references, and so on, until ultimately the justification of the newest work rests on that of the earliest in that particular science. Every paper is thus implicitly the whole history of its own particular subject, but the writer of it is probably ignorant of all the previous work except that on which his own immediately rests. This ignorance is clearly undesirable, and can be a source of much error.

Some speakers have stressed the importance of not detaching the history of scientific ideas and discoveries from that of the social conditions under which they arose. I think this is a mistake. The validity of any such idea or discovery does not depend in the least on the circumstances—social or any other—of its origin, and therefore the history of pure science can be written apart altogether from the external reasons for its coming into existence. And it not only can, but should, be so written. Then, and only then, can one effectively turn to the other, equally important, question of the conditions that gave rise to it. One can see the harm done by not separating these two studies in the Nazi evaluation of scientific work in terms of the race of its originator, the Communist evaluation in terms of its conformity to the philosophy of Marx and Engels, the frequent evasion of a purely rational argument by the attempt to show how it results from the psychology of its author, and so on. A true understanding of the social relations of science can be obtained only by writing first the history of science in itself, and then, as a separate investigation, considering why its successive steps occurred when, where, and how they did.

SUMMARIZING REMARKS

PHILIPP G. FRANK

Harvard University

THE discussions have centered about three major questions concerning our topic of the history, philosophy and sociology of science: (1) What are the needs that should be met?, (2) In what ways can these needs be met?, and (3) What can the National Science Foundation do to help meet them?

The techniques and products of science have resulted in society's placing a high value on science. However, science is regarded as a special field, one that is not in the mainstream of the general ways of man. It has contributed materially to the welfare of man but the power of scientists to shape the world is small compared to the power wielded by lawyers, politicians, businessmen and the like. Scientists are considered ignorant in the ways of man—an accusation which in many respects is true. One of the problems of the history, philosophy, and sociology of science is to make scientists less ignorant; to do this the unity of science and the relation between science and human behavior must be demonstrated.

Science is taught often in a dull way. Students learn it as a ready-made object and have no conception of science as a living thing with laws of growth and decay. For a true understanding of his own science, the young student must learn how principles and theories have developed.

We have inherited a certain stock of concepts. These concepts are not arbitrary inventions; they have a history that must be understood and a meaning that must be explained. When we cannot explain our concepts lucidly, we arrive at a time of "crisis" and science is accused of bankruptcy.

Science is essentially an attempt to describe observed facts by a system of concepts. There are some who would disagree, claiming that science represents a triumph of stubborn facts over concepts. But this is not true. Before we have formulated a theory, we have no basis for evaluating what is or is not a fact. Therefore, there can be no priority between facts and concepts—one cannot exist without the other and good science represents an interaction between the two.

If the philosophy of science can be considered the search for the rules according to which concepts and facts interact, then the history of science is a study of how these rules originated and how they have changed. Thus, from the beginning, the history of science and the philosophy of science have been connected very closely with each other and with science as a whole.

In order to understand these rules thoroughly one needs to approach their study from an historical point of view. Concepts of science appear brilliant and revolutionary when they are new, but become stale and a matter of course with age. For example, what is startling today about the law of inertia? When students are introduced to it, their reaction is boredom. Who has not known of this law? Who would expect any other kind of behavior from an inanimate object? To appreciate the significance of the law of inertia one has to understand the circumstances under which it was introduced, one has to understand and appreciate what was new about it and how the concept of inertia has since been used. This illustrates only one reason why no science teaching can be satisfactory without historical interpretations.

Science progresses in two ways: the accumulation of new facts and the internal evolution of the conceptual system into which the facts are fitted. It is the business of the philosophy of science to present and analyze the changing conceptual system of science. When this system remains constant, new facts are somehow fitted into existing concepts. Then science becomes a mere accumulation of facts. In such periods, philosophy of science is ignored or minimized in science teaching. But in such periods the advances in science are slight. However, in our century radical changes have occurred in the conceptual system of physics, and philosophy of science has become an essential part of physics teaching.

None the less, scientists have often failed to appreciate the value of philosophy to science. Yet, as Whitehead said, if a scientist does not consciously work out a philosophy, he still has one. He simply retains the philosophy absorbed from his nurse or his schoolmaster without change.

Hence, such a "chance philosophy" is of no value for the understanding of science. There are, of course, always some scientists who are interested in acquiring an adequate philosophy of science, but they normally find it difficult to get specific training. The courses in the philosophy of science that are given today in universities are usually to be found in philosophy departments. They are mostly restricted to "Deductive and Inductive Logic" and provide a very meager understanding of actual science. Other courses are in the hands of more or less competent amateurs who are primarily scientists, and only philosophers by predilection; they cannot devote enough time to becoming competent philosophers.

There have been great scientists who have failed in their intentions to be teachers in the philosophy of science. Good teachers in this field could probably be produced by a process of "natural selection." When competent amateurs are found, they should be encouraged. They are an important group, for these are the people who can increase interest and understanding by teaching science from a philosophical point of view. Among their science students will be found the future philosophers of science.

The history, philosophy, and sociology of science can explain the growing body "science" from a double aspect: it can explain it to scientists from the logical and empirical aspect to which they are accustomed. But conceptual systems are produced not only by physicists operating from the basis of known facts, but extra-scientific factors enter into the formulation of concepts. There is more to a given formula than the symbols in an equation. Society's role must not be minimized. The formula $f = ma$ (mass times acceleration equals force), for example, can be used in ballistics if the meaning of the symbols is explained from the logical and empirical aspect only. But if the student is to understand the formula fully and to use it in a very general way, this explanation would be too "dry." One has to add the historical psychological and sociological background from which the formula has emerged, or, in other words, the humanistic aspect.

These fields of history, philosophy, and sociology of science obviously have to be built up before they can help science. Recognition and support are basic to their development. The National Science Foundation can help develop these fields by two steps, both connected with the training of personnel. A substantial number of science students going through their regular training will go on to become science teachers. It is imperative that these students be exposed to philosophical and historical conceptions of their field so that they in turn can alert future students to these considerations. The basic manpower shortage is in competent professional personnel to train the present science teachers along these lines. Once we have a hard core of specialists whose primary interest is in the history, philosophy, and sociology of science, we can find jobs for them by having them train our future teachers of science. By being exposed to the philosophy and history of science, students will not become research workers in these fields, but they will become scientists and science teachers with a deeper "understanding" of science and its place among other human activities.

The discussions at this conference have returned time and again to certain basic needs—the need for personnel and the need for support. To this end, the most important recommendations are those involving fellowships and research support. The other mechanisms through which the Foundation aids the progress of science have, for the history, philosophy, and sociology of science, to be set up gradually. Research conferences need a common driving enthusiasm more than money. Summer-training institutes should be held when the teaching personnel is available. International travel would indeed be very valuable, for no international organization has been established in the philosophy and sociology of science, and comparative study would be extremely important. While science itself is approximately the same one in the whole world, the philosophical interpretations of science in different countries are very different from each other, indeed.

We appreciate the interest of the National Science Foundation in these fields and agree in recommending to the Foundation the establishment of an advisory panel for the history, philosophy, and sociology of science. This panel, by advising the Foundation on its general program in these areas and on the first steps to be taken, would aid the advance of research and training in these fields and thus help the Foundation in its ultimate aim of advancing science.

APPENDIX

1. SUMMARY OF RECOMMENDATIONS

RECOMMENDATIONS TO THE NATIONAL SCIENCE FOUNDATION

1. There should be established within the National Science Foundation framework an Advisory Panel for the History, Philosophy, and Sociology of Science. A combined panel for the three fields would serve to give unified direction to any efforts in these areas.

2. The most critical need is for fellowship support specifically for work in these interdisciplinary areas. There is a need for both pre-doctoral and post-doctoral fellowships in order to attract able scholars into these fields. Particularly important would be post-doctoral fellowships available to scientists who wish specialized training in the history, philosophy, and sociology of science.

3. There should be a program of research support for established scholars. At the present time, support for these fields is almost non-existent. National Science Foundation interest and encouragement of basic research would stimulate these areas and make them more attractive to prospective students. A research support program should help meet the needs of the two major groups in the field: specialists in these interdisciplinary areas and established scientists who are interested in research in the history, philosophy, and sociology of their field.

4. Travel support for attendance at international congresses should be made available. This is particularly true for the history of science which has an international organization and where the basic source materials for research are available in only a few selected locations throughout the world.

5. The programs of support initially should emphasize existing centers of activity in these areas. In this way, the aid given by research grants and fellowships will serve to help produce the maximum number of new people.

6. As the Foundation enters its fifth year, consideration should be given to the eventual writing of its history and a full evaluation of its influence. It is not too soon for the Foundation to consult historians of science, at least with respect to the preparation of materials for such a history.

7. The Foundation should consider giving support to conferences and summer seminars in these fields should specific needs arise.

RECOMMENDATION FOR THE DISCIPLINES

Appreciation and understanding of the contributions of the history, philosophy, and sociology of science should be stimulated in the university atmosphere. This must be done from within, and financial aid is not required. Interdisciplinary seminars have proven successful in many instances. A direct approach would be to increase the emphasis on history, philosophy, and sociology of science in the content of present science courses.

2. THE STEERING COMMITTEE

Harry Alpert, National Science Foundation, Liaison Representative.
Bernard Barber, Barnard College.
I. Bernard Cohen, Harvard University.
Philipp G. Frank, American Academy of Arts and Sciences.
Henry Margenau, Yale University.
Richard H. Shryock, The Johns Hopkins University, Chairman.

3. QUESTIONS ASKED OF DISCUSSION LEADERS

1. What is going on in the field with respect to research and training?

2. What are the sources of financial support in this area?

3. What personnel is available for research and teaching in these fields? How many? What is the quality and nature of their training?

4. How can research in this field be of aid to science?

5. How can this field be of aid to the educational process?

6. What are the research and training needs in this field with respect to specialists, scientists generally, and the educated public?

7. What role can the National Science Foundation play in support of research and education in this field? Which of the following programs of

the National Science Foundation might be considered in this connection:

Research support
Graduate fellowships
International travel
Conferences in support of science
Summer seminars
Training of science teachers
Exchange of scientific information

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